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SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

SECOND PAPER

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A preliminary study on this subject, indicating that common foods do have specific effects on the growth of swine, was published in 1909 jointly by the Ohio and Missouri Agricultural Experiment Stations, the experimental work having been conducted by the senior author of this paper at the Missouri Station in 1905-6.

In view of the superficial character of this earlier work, however, the conclusions could not be regarded as in any sense final. On this account, therefore, after a lapse of seven years, and after very great improvement in all of the conditions attending our work, we have conducted a second experiment involving the same fundamental considerations.

The difficulties of the problem are such that its complete solution, on a final basis, must await much further work, for a part of which we have not yet adequate scientific basis of method and fact; but in spite of these conditions our repetition of the experiment has not been without a contribution toward the desired end.

The object of this experiment was to study the effects on the growth of swine of rations composed as follows:

Lot	Ration
1.	Corn alone
2.	Corn; soy beans, 10.82:1
3.	Corn; linseed oil meal, 9.36:1
4.	Corn; wheat middlings, 2.81:1
5.	Corn; tankage, 18.84:1
6.	Corn; skim milk, 0.882:1
7.	Control lot; killed at beginning of experiment

Manifestly, in order to compare these rations on an equitable basis, the ratio of corn to supplement in the several lots must be such as to supply the main classes of nutriment, (protein and non-nitrogenous starch equivalent) in the same proportions (except in the ration of corn alone, which was fed in accord with the total amount of nutriment in terms as previously stated). The literature did not contain the digestion coefficients necessary to the computation of these rations; as a preliminary to this experiment, therefore, we conducted the extensive metabolism study with swine the results of which have been published in Ohio Agr. Exp. Station Bul. 271. For each of the above-mentioned foodstuffs, digestion coefficients were determined with five barrow pigs from the same litter. In the case of corn, two such sets of five digestion tests were made, one at the beginning and one at the end of the whole series. On this carefully established basis, then, we compounded from the above-mentioned foodstuffs the several "equi-nutritive" rations which were compared, the differences in results presumably being due to intimate differences in the kind rather than to differences in the amount of nutriment provided (except in the ration of corn alone).

One factor in the determination of the above-mentioned digestion coefficients requires mention at this time. The determination of the real digestibility of protein requires that we deduct from the apparently indigestible total protein of the feces that fraction designated metabolic protein, which has an origin other than as an indigestible food residue. The determination of metabolic protein on a scientific basis is quite out of the question in our present state of knowledge, and the nature of the problem is such that we are unable to foresee the method of its solution. All known methods of estimation of metabolic protein are highly conventional. It is not possible to prove their accuracy. This, however, can be said in support of the pepsin-hydrochloric acid method as we used it for this determination: milk protein, which presumably is entirely digestible, was made to appear digestible to the extent of 99.12 percent, the several errors involved in the method apparently being of such kind and degree as almost exactly to balance each other. As to the accuracy of the method as applied to other foods we have not even this somewhat doubtful measure.

Regarding the classes of nutriment other than protein, there is the same logical necessity for correction of total amounts excreted in the feces, by the subtraction of metabolic wastes, but there are no known means of making these corrections in even an approximate way; fortunately it is also true that in relation to the particular problem at hand these other considerations are of slight significance.

Thirty-five pigs, all pure-bred Duroc-Jerseys, were used in this experiment. These pigs were selected from a lot of 63 of approximately the same age which had been bred and reared for this especial work. The nine dams were all of the same type, and closely related. Two sires were used.

During four months these pigs were fed, each litter by itself and all on the same foods;—corn, skim milk, linseed oil meal and tankage, with salt and bone flour allowed *ad libitum*. The pigs were grown rather slowly, at a rate of about 0.9 lb. daily. Each litter was kept in a lot 36 ft. square, and isolated from all others in order to prevent the spread of parasites, there having been lung-worms in the herd in previous years.

During this time the pigs were closely observed, and note was made of any such irregularity of behavior or development as might indicate abnormality. At the end of this growing period the 35 pigs were selected from the 63. In this selection we took from each litter those individuals which, with the same chance, had made most nearly the same growth, and threw out all which for any reason whatever might detract from the uniformity of the experimental lots. Every pig selected was apparently in every way normal, and satisfactory for the purpose. The 35 pigs were then taken to the paved feeding pens (see illustration, page 146) and divided into 7 lots of 5 each, the litters being broken up, and the sexes being as nearly uniformly apportioned as possible. The pigs were fed individually, and the amount fed to each was in accord with the live weight. After two weeks' such feeding, the pigs were redistributed, so as to have in each lot the same live weight, and putting into the control lot, which was to be killed at the beginning of the experiment, those which had, during these two weeks, gained in weight least nearly as did the average. On September 20, 1913, the experimental feeding began. On September 22, the control lot was killed. The feeding continued during 12 weeks, and a final slaughter test was conducted on Dec. 15.

Mention has been made of lung-worms. There had been no sign of infestation with this parasite at the time the experiment began. At intervals, during the summer preceding this experiment, a number of the less thrifty pigs were killed, and the lungs were microscopically examined with care. No lung-worms were found. Toward the close of the experiment, however, there was a little coughing, and the slaughter test at the end of the experiment showed a few worms to be present in the lungs of a considerable proportion of the pigs. Since it was not until late in the experiment

that this parasite made its presence known, it is our judgment that the infestation was not sufficient appreciably to affect results. This parasite is an especially difficult one to control since there is no way of determining a slight infestation.

During the course of the experiment the pigs, irrespective of the food received, did not eat quite as heartily as is customary. A part of this was due to the fact that they were fed individually. Pigs so fed are not so greedy as when fed together. The spirit of competition, at the trough, undoubtedly whets the appetite. Another possible cause for their moderate appetites is that the fences and troughs had been painted with a coal-tar paint. The pigs gnawed off considerable amounts of this coating. Perhaps the effect of the coal-tar distillate with which the paint was mixed was unfavorable.

The pigs in each lot were numbered from 1 to 5 by shearing spots on the back. No difficulty was experienced at feeding time in getting the pigs to go into the right stalls. As will be observed in the illustration on page 147 the gates to these stalls were raised by cords passed over pulleys in a frame above them and then to the fence next to the feeding alley, the attendant remaining outside the pen. By raising a gate only when the right pig was in front of it, the animals very soon learned where they belonged, and one man did the feeding without difficulty.

The foods were weighed to the gram, and were placed in the feeding troughs in the dry form, and afterward were mixed with water. The pigs were weighed individually once each week, and each week's weights were used as a basis for the next week's feeding. Throughout the experiment the foods were apportioned in accord with the live weight, on the basis of digestible nutrients contained; that is, in each lot, each pig was given the same amount of digestible nutriment per unit of live weight.

As is well known this method of apportioning the food is not entirely fair since it fails to recognize variations in the composition of the increase in weight, which may be more largely fat in one case than in another. This tends to feed the animal which has fattened much and grown little a larger amount in relation to its actual requirements than it does the animal which has grown more and fattened less.

Much individual variation was observed in the response of the pigs to the food, especially in those lots which received the less acceptable rations, and many departures from the feeding schedule were necessitated by unwillingness of the pigs to coöperate. A

considerable measure of compromise is necessary in any exacting program in which 30 pigs are expected to behave alike. They are not machines.

Our principal difficulties in the feeding of the pigs were with those which received corn alone, and those on the ration of corn and soy beans. The pigs on corn alone ate fairly well at first, but soon tired of the diet. Pig No. 5 especially seemed ravenously hungry, but entirely unwilling to eat corn, except to save his life. Pig No.1, on the other hand, did well on corn alone, and during the 84 days' feeding did not at any time fail to clean up all of his corn. The lot on corn and soy beans evinced an unaccountable dislike for the ration. The corn was of excellent quality and the soy beans seemed in every way clean and sweet. The variety used was Medium Green. Another variety was also tried but without greater success. The dislike of pigs for soy beans is an individual peculiarity which is not possessed by all, but which is rather common.

In as many respects as possible the observations have been made on individual animals; thus, the feeding and weighing of the animals, the weights of parts, tissues and organs in the slaughter test, the blood counts, and certain data on the femora and tibiae were made on this basis, in recognition of the fact that the significance of differences between lots is rendered more clear by a knowledge of the variability of the individuals within the lots; the chemical analyses, however, have been made on composite samples representing the five individuals of an experimental lot. While individual chemical analyses will be necessary to the final establishment of the facts as to the effects of foods on the composition of animals, there is much that can be learned from analyses of composite samples, especially through the character of observations upon several lots in series, and through other corroborative evidence such as the mineral metabolism study on the same rations, which preceded this experiment. Such analyses of composite samples have a further value as indications of the nature and degree of the facts or conditions of interest, these being matters regarding which one wishes to be assured, through preliminary surveys, before undertaking the very considerable labor of complete, individual, chemical accountings for large numbers of animals.

COMPOSITION OF FOODSTUFFS

The composition of the foods was as stated in Table I, page 116. The experiment was started on the basis of earlier analyses, which were found to be faulty. The proportions of corn to supplement

were readjusted after the correction of the food analyses. This circumstance accounts for the slight divergence of the nutritive ratios of the rations (Table V, p. 120) from the proportion 1:6.5 as originally planned.

TABLE I. COMPOSITION OF FOODS—Percent Fresh Basis

Food	Protein	N-free extract	Crude fiber	Fat	Ash	Moisture
Corn	9.475	70.31	2.61	4.194	1.294	12.118
Soy beans	38.41	19.57	8.23	19.017	5.059	9.71
Linseed oil meal	31.47	33.11	11.71	8.095	5.592	10.02
Wheat middlings	16.66	57.16	5.21	5.658	3.537	11.774
Tankage	61.19	1.62	4.71	8.00	15.76	8.719
Skim milk	3.211	5.52	. ...	0.177	.....	.... .

DIGESTIBLE NUTRIENTS IN FOODS

The digestible nutrients of the foodstuffs are set forth in Table II, below. These data were obtained from the food analyses as in Table I and the digestion coefficients for these foods as published in our Ohio Station Bul. 271. The lack of agreement between our digestion coefficients and other published coefficients for the same foods, and consequently between the proportions in which we fed the corn and supplements, and the usual proportions in which the same are fed, is due to the fact that in the determination of digestibility of protein we made a correction for metabolic protein. This has not been customary. The usually accepted digestion coefficients for protein really represent "apparent digestibility" in the sense that they have been computed from the total feces nitrogen without correction for metabolic nitrogen.

TABLE II. DIGESTIBLE NUTRIENTS IN FOODS
Grams per Kilogram of Foods

Food	Protein	N-free extract	Fat	Crude fiber	Total N-free starch equivalent
Corn	88.3	654.1	26.8	18.0	732.4
Soy beans	358.9	198.5	159.3	24.3	581.2
Linseed oil meal	289.6	263.8	50.0	22.9	399.2
Wheat middlings	156.4	471.3	44.8	7.4	579.5
Tankage	519.1	25.0	111.6	—47.6	228.5
Skim milk	31.8	56.7	2.9	... .	63.2

FEED AND GAINS IN LIVE WEIGHTS

The feed consumed, in grams per week, is stated in Table III, p. 118, and the live weights, at the end of each week, in Table IV, p. 119. In the computation of the relative efficiency of the several rations, from the data in Tables III and IV, certain of these data were eliminated. Thus, because of the disturbance incident to the collection of blood samples during the 12th week, the live weights of Dec. 14 were considered unrepresentative, and the feeding records of this last period were not used. Also, only one of the pigs receiving soy beans ate this food in the amount desired during a long enough time to make the results of value. Further, certain other pigs indulged in hunger strikes and other irregularities of behavior, at times during the experiment, on account of which certain portions of their records were thrown out. The first column of figures in Table V, p. 120, indicates the extent of these several compromises imposed upon us by the more or less unwilling subjects of the experiment.

RELATIVE EFFICIENCY OF NUTRIENTS FROM DIFFERENT FOODS

In Table V, p. 120, the last column to the right indicates the kilograms of nutriment, in terms of protein and non-nitrogenous starch-equivalent, required to make one kilogram of increase in live weight. In the consideration of these data the reader should bear in mind the peculiar conditions attending this test. In the usual comparisons of rations the effect of the relative amounts in which the rations are eaten is not excluded; other things being equal, the more palatable ration makes the more economical gain in weight, because, since the ration will be eaten in larger amount than others, a larger percentage of the nutriment will be used for increase and a smaller percentage for maintenance. In the experiment here recorded this factor is eliminated, and, therefore, it is quite possible that a different order of relative efficiency would prevail, on this account, from that which would result from a comparison of the same rations on the usual basis of *ad libitum* food consumption.

The nutriment required per unit of gain in weight in Lot 1, which received corn alone is rather uniformly high, and the average is higher than any other lot except No. 5, which received tankage. The high cost (in nutriment) of the increase in weight in this lot (No. 5) is not in accord with the accepted belief that the feeding of proteid supplements with corn lowers the amount of nutriment required per unit of increase.

TABLE III. FOOD CONSUMED BY EACH PIG—Grams per Week

Lot and ration	Pig No.	Sept. 20–Sept. 27	Sept. 27–Oct. 4	Oct. 4–Oct. 11	Oct. 11–Oct. 18	Oct. 18–Oct. 25	Oct. 25–Nov. 1	Nov. 1–Nov. 8	Nov. 8 Nov. 15	Nov. 15–Nov. 22	Nov. 22–Nov. 29	Nov 29 Dec. 6	Dec. 6–Dec. 14
I Corn	1	13286	14140	14882	14714	13075	14121	14560	13912	15750	16758	16450	18928
	2	11620	12194	13202	12628	11425	12339	12558	11712	13188	13916	13580	15936
	3	9375	10180	10984	11348	9152	9450	7400	9287	9720	9675	10450	11400
	4	10556	11088	11648	11634	10375	11205	11662	11250	12698	13258	13216	15232
	5	9618	9618	10584	10416	9225	6083	5200	5950	6875	4850	5200	6400
II Corn, soy beans	1	6494	11004	11000	10512	8800	6799	5900	7675	10100	10800	10050	2900
	2	10080	10920	11858	11396	10237	11056	11480	11012	12600	13258	12992	15760
	3	8352	11410	12264	12040	8564	8500	8600	9500	11500	8450	7200	6300
	4	9210	8364	9787	11276	10175	10725	11700	10725	8950	8100	5400	5200
	5	10318	10962	12054	6372	4552	8900	6900	7000	8800	10300	10612	12736
III Corn; linseed oil meal	1	10164	10906	11704	11312	10437	11272	11382	10837	12460	13230	13048	12654
	2	14266	15260	9752	14876	13137	14188	14868	13925	16128	16870	16534	19088
	3	9165	9417	11116	10808	9937	10732	11172	10675	12068	13090	12922	14864
	4	9534	10290	10878	10654	9500	10260	10724	10075	11718	12390	10528	14048
	5	14224	14882	15848	15414	13975	15093	15428	15000	10605	13400	10000	12000
IV Corn; wheat middlings	1	11382	12264	13188	12852	11512	12433	12950	12437	14392	13730	10100	6000
	2	10332	11004	11592	11410	10225	11043	11522	11062	12600	13454	13174	15904
	3	12096	12600	13524	13174	11912	12865	13342	12712	14784	15428	15050	10500
	4	13455	14952	15624	15442	14112	15241	15932	15237	17528	17324	13556	16600
	5	9984	11214	12096	11802	10562	11407	12136	11637	13426	14168	12396	15904
V Corn; tankage	1	12642	13132	14238	13902	12200	13176	13748	12962	14966	15666	15358	17600
	2	11088	11816	12852	12446	11175	10293	9300	11625	13188	13762	13552	15792
	3	10710	11494	11774	11564	10287	11110	11382	10750	12138	12810	12334	14368
	4	10346	10878	11326	11032	8498	8050	8300	8125	9300	10400	8300	11200
	5	11700	13006	13874	13482	12100	13068	13258	12737	14518	14882	14574	17264
VI Corn; milk	1	**14280**	**15050**	**13090**	**12880**	**11625**	**12555**	**13090**	**12310**	**14070**	**14840**	**14630**	**17039**
		10794	11354	12334	12110	10975	11853	12348	11587	13286	13972	13818	16048
	2	**10850**	**11620**	**10290**	**10290**	**9187**	**9922**	**10640**	**10125**	**11620**	**12320**	**12180**	**14239**
		8190	8778	9688	9702	8675	9369	10038	9550	10976	11620	11466	13424
	3	**14420**	**15540**	**13790**	**13580**	**12250**	**13230**	**13790**	**13060**	**14910**	**15820**	**15820**	**18561**
		10864	11746	12978	12824	11537	12460	13006	12312	14056	14966	14896	17520
	4	**11690**	**12390**	**10640**	**10570**	**9562**	**10327**	**10990**	**10560**	**12180**	**12880**	**12740**	**14882**
		8820	9352	10038	9982	9025	9747	10374	9962	11494	12180	11984	14064
	5	**14490**	**15470**	**13440**	**13300**	**11937**	**12892**	**13440**	**12625**	**14700**	**15540**	**15120**	**17602**
		10934	11676	12656	12544	11237	12136	12740	11925	13832	14616	14252	16640

Note: In the lower section of the table the bold-face figures represent milk, the light-face figures corn.

TABLE IV. INDIVIDUAL LIVE WEIGHTS OF PIGS—Kilograms

Lot and ration	Pig No.	1 Sept. 20	2 Sept. 27	3 Oct. 4	4 Oct. 11	5 Oct. 18	6 Nov. 1	7 Nov. 8	8 Nov. 15	9 Nov. 22	10 Nov. 29	11 Dec. 6	12 Dec. 14
I	1	65.2	69.4	72.8	77.2	79.6	85.6	89 8	90.8	96.6	100.8	103.6	106.2
	2	57.0	59.8	64.6	66.2	69.6	73.8	75.6	76.0	80.2	83.2	87.2	87.2
Corn	3	59.4	57.0	59.8	63.0	64.8	66.4	67.6	69.0	72.0	73.4	76.6	77.8
	4	51.8	54.4	57.0	61.0	63.2	68.6	72.6	73.2	76.4	81.0	83.4	88.0
	5	47.2	47.2	51.8	54.6	56.2	56.4	57.4	56.0	58.4	55.8	56.8	56.8
II	1	55.6	54.8	60.4	62.2	64.2	65.4	61.6	63.2	68.0	72.6	76.0	70.0
	2	50.2	54.4	58.8	60.6	63.2	68.6	72.2	73.8	77.6	80.8	87.6	90.6
Corn;	3	55.2	56.8	60.8	64.0	66.8	68.6	70.8	71.8	76.8	78.4	80.0	72.8
soy beans	4	65.2	65.0	68.0	69.8	72.8	78.6	81.2	82.6	85.8	87.4	87.4	86.2
	5	51.4	54.6	59.8	62.2	....	....	....	....	....	66.0	70.8	71.6
III	1	49.0	52.6	56.4	58.4	62.6	65.8	68.8	70.6	75.0	79.6	84.2	82.6
	2	68.8	73.6	77.4	77.6	78.8	86.0	88.4	91.4	95.6	99.6	102.8	105.2
Corn; linseed	3	47.6	49.0	53.6	55.8	59.6	64.6	67.8	68.4	74.2	77.8	80.0	80.0
oil meal	4	46.0	49.6	52.4	55.0	57.0	62.6	64.0	66.4	70.2	73.4	75.6	79.4
	5	68.6	71.8	76.4	79.6	83.8	89.2	95.2	98.0	99.0	103.8	104.2	105.2
IV	1	54.2	58.4	62.8	65.6	68.2	74.0	78.0	80.6	82.6	85.6	87.2	84.8
	2	49.2	52.4	55.2	58.2	60.6	65.8	69.4	70 6	75.4	78.4	84.6	86.2
Corn; wheat	3	57.6	60.0	64.4	67.2	70.6	76.2	79.8	82.8	86.4	89.6	94.4	91.6
middlings	4	69.0	71.2	74.4	78.8	83.6	91.0	95.6	98.2	104.4	107.4	107.6	109.2
	5	51.2	53.4	57.6	60.2	62.6	70.2	73.0	75.2	79.4	83.0	84.6	86.4
V	1	61.8	64.2	69.4	72.6	74.0	80.4	83.2	85.8	89.8	93.6	95.8	99.2
	2	54.2	57.8	62.6	65.0	67.8	73.8	74.6	75.6	78.9	82.6	86.0	89.0
Corn;	3	52.4	56.2	57.4	60.4	62.4	66.6	69.0	69.6	73.4	75.2	78.2	79.8
tankage	4	50.6	53.2	55.2	57.6	59.2	60.2	61.0	62.2	64.0	67.6	66.8	68.4
	5	61.6	63.6	67.6	70.4	73.4	77.6	81.8	83.2	85.3	88.8	94.0	95.0
VI	1	61.2	64.4	68.0	71.6	75.4	81.4	84.0	86.0	90.4	95.0	98.6	101.0
	2	46.4	49.8	53.4	57.4	59.6	66.2	69.2	71.0	75.2	78.8	82.4	83.4
Corn;	3	61.6	66.6	71.6	75.8	79.2	85.8	89 2	91.0	96.8	102.4	107.6	112.0
skim milk	4	50.0	53.0	55.4	59.0	62.0	68.4	72.2	74.4	78.8	82.4	86.4	89.8
	5	62.0	66.2	69.8	74.2	77.2	84.0	86.4	89.6	94.6	98.0	102.2	105.2

TABLE V. RELATIVE EFFICIENCY OF NUTRIENTS FROM DIFFERENT FOODS—Kilograms

Lot and ration	Pig No.	Period of observation Weeks—to—	Total corn	Total supplement	Gain per head per day	Digestible nutrients			
						Total protein	Total non-nitr. starch equivalent	Nutritive ratio, 1:—	Nutriment per kilo. gain in weight
I	1	1—11	161.648	.....	0.499	14.274	118.391	8.29	3.455
	2	1—11	138.362	.....	0.392	12.217	101.336	"	3.760
	4	1—11	128.590	.....	0.410	11.355	94.179	"	3.340
Corn	5	1—4	40.236	.....	0.321	3.553	29.469	"	3.669
Average.....	..	....	.....	. .	0.406	.....	.....	....	3.556
II	2	1—11	116.155	10.734	0.486	14.108	91.311	6.47	2.819
Corn; soy beans									
III	1	1—11	114.514	12.239	0.457	13.656	88.756	6.50	2.909
	2	1, 2, 4—11	135.541	14.511	0.483	16.170	105.063	"	3.587
	3	1—11	109.411	11.690	0.421	13.046	84.800	"	3.020
Corn; linseed oil meal	4	1—11	105.296	11.255	0.384	12.557	81.612	"	3.181
	5	1—8	108.285	11.579	0.525	12.915	83.930	"	3.294
Average.....	..	...	.....	. ....	0.454	... ..	.....	....	3.225
IV	1	1—9	83.797	29.613	0.451	12.030	78.534	6.53	3.189
	2	1—11	94.014	33.404	0.460	13.525	88.214	6.52	2.874
	3	1—11	108.824	38.664	0.478	15.656	102.109	6.53	3.200
Corn; wheat middlings	4	1—9	101.606	35.917	0.562	14.589	95.230	6.52	3.102
	5	1 10	87.422	31.010	0.454	12.569	81.998	6.52	2.974
Average...	..	.. .	..... .	.....	0.481	.....	.....	....	3.068
V	1	1—11	144.333	7.657	0.442	16.720	107.459	6.43	3.652
	2	1—4, 8—11	95.187	5.142	0.446	11.074	70.890	6.40	3.279
	3	1—11	119.977	6.376	0.335	13.904	89.328	6.42	4.001
Corn; tankage	5	1—11	139.787	7.412	0.421	16.191	104.074	6.43	3.712
Average..... ...	..	....	.... .	. ....	0.411	.	.....	....	3.661
VI	1	1—11	133.431	152.576	0 486	16.634	107.368	6.45	3.316
	2	1—11	108.052	122.377	0.468	13.433	86.871	6.47	2.786
	3	1—11	141.645	160.584	0.597	17. 14	113.890	6.47	2.859
Corn; skim milk	4	1—11	112.958	128.061	0.473	14.046	90.823	6.47	2.881
	5	1—11	138.548	157.237	0.522	17.234	111.410	6.46	3.200
Average.	..	....	... ...	.....	0.509	.....	.....	...	3.008

The one pig in Lot 3 which ate the soy bean ration satisfactorily made a very economical increase in weight. Only one other pig among the thirty made so large a gain in weight per unit of food consumed. This one was in the lot which received skim milk. This result (with the soy bean ration), while of limited value, since it represents but one pig, agrees with the published evidence which accords to soy beans a very high nutritive value.

In our judgment the evidence as to the relative economy of the increase in weight in Lots 3 and 4, which received linseed oil meal and wheat middlings, would not warrant a comparative statement.

The evidence that the ration of corn and milk, No. 6, made the most economical gain in weight, is readily acceptable.

These data on relative economy of gain in weight, taken as a whole, are not highly satisfactory; however, we report them as they came to us.

SLAUGHTER RECORDS

Table VI, p. 122, sets forth the slaughter records. From these data it is apparent that, in general, these rations are better qualified to produce normal development of flesh than of bone. As compared with the check lot, No. 7, the corn lot, No. 1, made only a slight increase in weight of bone; the soy bean lot, No. 2, made practically no increase, while with the other lots the gain in weight of bone was considerably larger. The lot which received skim milk (No. 6) produced much more bone than any other lot. This lot also produced the greatest weight of flesh, leaf fat, blood, heart, kidneys and spleen. Further, the back-fat was thicker than in any other lot.

The corn lot, No 1, was characterized by light bones, blood and heart, and comparatively heavy leaf fat.

The record of the soy bean lot reflects the undernourishment of these individuals. The record of Pig No. 2 in this lot, which is the only individual that kept up with the feed schedule, was not markedly different from that of Lots 3, 4 and 5.

Table VII, p. 124, sets forth the slaughter data divided by the gross-dressed weight. These figures show that the proportion of bone in the carcasses of the check lot was much higher than in any of the lots which were fed. The blood, brain, liver, kidneys and spleen of the check lot were all heavier, while the leaf fat was lighter, in comparison with the gross-dressed weight, than the same parts of the lots which were fed.

Among the several lots, No. 3, which received linseed meal, appears to have had the largest proportion of flesh and of leaf fat, and the smallest proportion of bone, in relation to the gross-dressed carcass, of any lot in the series.

TABLE VI. SLAUGHTER RECORDS

Lot and ration	Pig No.	Live weight Kg.	Gross dressed weight Kg.	Flesh Kg.	Skin Kg.	Flesh (incl. skin) Kg.	Bone Kg.	Leaf fat Kg.	Back fat, shoulder Mm.	Back fat, middle Mm.	Back fat, rump Mm.	Blood Kg.	Brain Kg.	Heart Kg.	Liver Kg.	Kidneys Kg.	Lungs Kg.	Spleen Kg.
VII	1	44.8	33.125	27.340	2.089	29.429	2.890	1.135	32	20	28	1.628	.090	.115	.985	.121	.250	.061
	2	60.2	46.033	37.088	3.529	40.617	4.658	1.636	45	30	35	2.084	.096	.155	1.065	.163	.329	.059
	3	48.0	37.174	29.970	2.544	32.514	3.646	1.256	45	25	28	1.828	.088	.142	.849	.144	.281	.054
Check lot	4	74.2	57.820	47.211	3.935	51.146	5.246	1.947	52	33	38	2.781	.093	.184	1.421	.210	.324	.064
	5	61.6	46.088	36.917	3.765	40.682	4.493	1.202	40	33	30	2.224	.082	.148	1.161	.181	.282	.060
Average.		57.8	44.048	35.705	3.172	38.878	4.187	1.435	43	28	32	2.109	.090	.149	1.096	.164	.293	.060
I	1	106.2	80.485	70.343	3.946	74.289	5.491	4.280	55	45	43	2.997	.106	.253	1.398	.270	.508	.079
	2	87.2	67.130	58.903	3.136	62.039	4.475	3 694	50	45	40	....	.099	.209	1.526	.291	.412	.059
	3	77.8	55.806	48.388	2.672	51.060	3.773	2 988	40	35	40	2.465	.110	.182	1.795	.188	.365	.059
Corn	4	88.0	66 435	59.136	2.967	62.103	3.839	4.050	50	45	40	2.597	.115	.209	1.405	.206	.383	.079
	5	56.8	41.056	34.608	1.999	36.607	3.703	1.488	35	25	30	1.923	.102	.145	1.105	.139	.363	.046
Average		83.2	62.182	54.276	2.944	57.220	4.256	3.300	46	39	39	2.496	.106	.200	1.446	.219	.406	.064
II	1	70.0	54.433	47.582	2.047	49.629	4.243	2.582	35	25	35	2.083	.105	.201	1.054	.156	.352	.060
	2	90.6	70.159	62.044	2.768	64.812	4.514	3.894	52	37	40	2.257	.086	.218	1.544	.211	.579	.077
	3	72.8	58.275	52.152	2.476	54.628	3.597	3.088	40	35	33	2 022	.095	.208	1.029	.173	.347	.070
Corn;	4	86.2	64.923	56.563	2.702	59.265	4.075	3.970	45	28	35	2.232	.089	.248	1.437	.177	.369	.061
soy beans	5	71.6	55.738	47.784	2.656	50.440	4.566	2.602	42	30	35	1.827	.082	.213	1.105	.158	.363	.055
Average. . .		78.2	60.706	53.225	2.530	55.755	4.199	3.227	43	31	36	2.084	.091	.218	1.234	.175	.402	.065
III	1	82.6	63.880	55.225	3.524	58.749	4.233	3.520	45	35	40	2.320	.102	.198	1.357	.192	.322	.066
	2	105.2	80.925	71.466	4.214	75.680	5.581	3.582	45	38	40	3.159	.103	.310	1.625	.265	.542	.096
	3	80.0	61.975	54.631	2.840	57.471	3.792	3.332	50	33	35	2.154	.099	.221	1.619	.208	.392	.068
Corn;	4	79.4	58.380	50.662	2.720	53.382	3.898	3.462	43	33	40	2.435	.102	.194	1.526	.200	.615	.066
linseed oil meal	5	105.2	85.105	77.483	4.071	81.554	4.293	5.560	60	50	53	3.092	.105	.328	1.308	.210	.706	.085
Average.....		90.5	70.053	61.893	3.474	65.367	4.359	3.891	49	38	42	2.632	.102	.250	1.487	.215	.515	.076

TABLE VI. SLAUGHTER RECORDS—Concluded

Lot and ration	Pig No.	Live weight Kg.	Gross dressed weight Kg.	Flesh Kg.	Skin Kg.	Flesh (incl. skin) Kg.	Bone Kg.	Leaf fat Kg.	Back fat, shoulder Mm.	Back fat, middle Mm.	Back fat, rump Mm.	Blood Kg.	Brain Kg.	Heart Kg.	Liver Kg.	Kidneys Kg.	Lungs Kg.	Spleen Kg.
IV	1	84.8	68.151	57.507	4.184	61.691	5.361	3.118	65	38	45	2.680	.108	.217	.969	.219	.374	.090
	2	86.2	64.484	56.485	3.211	59.696	4.131	3.526	40	32	40	2.830	.101	.212	1.540	.241	.408	.072
Corn;	3	91.6	73.683	64.004	4.168	68.172	4.911	3.080	50	40	45	2.569	.085	.264	1.105	.250	.557	.079
wheat	4	109.2	86.065	74.799	4.894	79.693	5.157	3.702	60	50	50	3.434	.090	.280	1.486	.311	.397	.114
middlings	5	86.4	67.571	59.499	3.412	62.911	3.915	3.156	55	47	50	2.597	.100	202	1.405	.222	.327	.085
Average.		91.6	71.991	62.459	3.974	64.433	4.695	3.316	54	41	46	2.822	.097	.235	1.301	.249	.413	.088
V	1	99.2	80.522	71 322	3.666	74.988	4.850	3.426	60	40	50	2.682	.100	.265	1.179	.238	.422	.089
	2	89.0	70.859	61.531	3.806	65.337	4.879	3.102	60	43	45	3.005	.098	.237	1.077	.229	.422	.077
	3	79.8	62.428	53.276	2.918	56.194	4.276	2.678	55	35	35	2.379	.105	.287	1.091	.225	.516	.090
Corn;	4	68.4	53.454	47.192	2.546	49.738	4.066	2.708	50	40	35	1.853	.095	.240	.873	.199	.413	.081
tankage	5	95.0	76.014	66.160	3.490	69.650	5.045	3.708	60	35	40	2.847	.101	.243	1.156	.246	.379	.070
Average..		86.3	68.655	59.896	3.285	63.181	4.623	3.124	57	39	41	2.553	.100	.254	1.075	.227	.430	.081
VI	1	101.0	82.203	69.213	4.263	73.476	5.441	3.926	65	50	45	2.666	.102	.309	1.112	.277	.613	.103
	2	83.4	66.348	56.918	3.564	60.482	4.693	4.010	50	38	43	2.682	.105	.280	1.312	.213	.360	.080
	3	112.0	90.366	77.847	5.583	83.430	5.850	4 638	65	45	50	3.520	.105	.279	1.525	.290	.422	.101
Corn;	4	89.8	72.416	62.524	4.630	67.154	4.926	2.794	60	47	52	2.873	.103	.267	1.092	.318	.593	.082
skim milk	5	105.2	85.798	75.341	4.434	79.775	5.218	4.982	65	50	60	. ...	.108	.327	1.262	.290	.410	.086
Average. .		98.3	79.426	68.369	4.495	72.863	5.226	4.070	61	46	50	2.935	.105	.292	1.261	.278	.480	.090

TABLE VII. RELATIVE DEVELOPMENT OF PARTS

Lot and ration	Pig No.	Relation gross dressed to live weight	Relation of parts to gross dressed weight									
			Flesh (incl. skin)	Bone	Leaf fat	Blood	Brain	Heart	Liver	Kidneys	Lungs	Spleen
VII	1	.7394	.8884	.0872	.0343	.0491	.00272	.00347	.0297	.00365	.00755	.00184
	2	.7647	.8823	.1012	.0355	.0453	.00209	.00337	.0231	.00354	.00715	.00128
	3	.7745	.8746	.0981	.0338	.0492	.00237	.00382	.0228	.00387	.00756	.00145
Check lot	4	.7792	.8846	.0907	.0337	.0481	.00161	.00318	.0246	.00363	.00560	.00111
	5	.7482	.8827	.0975	.0261	.0483	.00178	.00321	.0252	.00393	.00612	.00130
Average		.7612	.8825	.0949	.0327	.0480	.00211	.00341	.0251	.00372	.00680	.00140
I	1	.7579	.9230	.0682	.0532	.0372	.00132	.00314	.0174	.00335	.00631	.00098
	2	.7698	.9242	.0667	.0550	.....	.00147	.00311	.0227	.00433	.00614	.00088
	3	.7173	.9150	.0676	.0535	.0442	.00197	.00326	.0322	.00337	.00654	.00106
Corn	4	.7549	.9348	.0578	.0610	.0391	.00173	.00315	.0211	.00310	.00577	.00119
	5	.7228	.8916	.0902	.0362	.0468	.00248	.00353	.0269	.00339	.00884	.00112
Average		.7446	.9177	.0701	.0518	.0418	.00179	.00324	.0241	.00351	.00672	.00105
II	1	.7776	.9117	.0779	.0474	.0383	.00193	.00369	.0194	.00287	.00647	.00110
	2	.7744	.9238	.0643	.0555	.0322	.00123	.00311	.0220	.00301	.00825	.00110
	3	.8005	.9374	.0617	.0530	.0347	.00163	.00357	.0177	.00297	.00595	.00120
Corn; soy beans	4	.7532	.9129	.0628	.0611	.0344	.00137	.00382	.0221	.00273	.00568	.00094
	5	.7785	.9049	.0819	.0467	.0328	.00147	.00382	.0198	.00283	.00651	.00099
Average		.7768	.9181	.0697	.0527	.0345	.00153	.00360	.0202	.00288	.00657	.00107
III	1	.7734	.9197	.0663	.0551	.0363	.00160	.00310	.0212	.00301	.00504	.00103
	2	.7692	.9352	.0690	.0443	.0390	.00127	.00383	.0201	.00327	.00670	.00119
	3	.7747	.9273	.0612	.0538	.0348	.00160	.00357	.0261	.00336	.00633	.00110
Corn; linseed oil meal	4	.7353	.9144	.0668	.0593	.0417	.00175	.00332	.0261	.00343	.01050	.00113
	5	.8090	.9583	.0504	.0653	.0363	.00123	.00385	.0154	.00247	.00830	.00100
Average		.7723	.9310	.0627	.0556	.0376	.00149	.00353	.0218	.00311	.00737	.00109

TABLE VII. RELATIVE DEVELOPMENT OF PARTS – Concluded

Lot and ration	Pig No.	Relation gross dressed to live weight	Relation of parts to gross dressed weight									
			Flesh (incl. skin)	Bone	Leaf fat	Blood	Brain	Heart	Liver	Kidneys	Lungs	Spleen
IV Corn; wheat middlings	1	.8037	.9052	.0787	.0458	.0393	.00158	.00318	.0142	.00321	.00549	.00132
	2	.7481	.9257	.0641	.0547	.0439	.00157	.00329	.0239	.00374	.00633	.00112
	3	.8044	.9252	.0667	.0418	.0349	.00115	.00358	.0150	.00339	.00756	.00107
	4	.7881	.9260	.0599	.0430	.0399	.00105	.00325	.0173	.00361	.00461	.00132
	5	.7821	.9310	.0579	.0467	.0384	.00148	.00299	.0208	.00329	.00484	.00126
Average.....		.7853	.9226	.0655	.0464	.0393	.00137	.00326	.0182	.00345	.00577	.00122
V Corn; tankage	1	.8117	.9313	.0602	.0425	.0333	.00124	.00329	.0146	.00296	.00524	.00111
	2	.7962	.9221	.0689	.0438	.0424	.00138	.00334	.0152	.00323	.00596	.00109
	3	.7823	.9001	.0685	.0429	.0381	.00168	.00460	.0175	.00360	.00827	.00144
	4	.7815	.9305	.0761	.0507	.0347	.00178	.00449	.0163	.00372	.00773	.00152
	5	.8001	.9163	.0664	.0488	.0375	.00133	.00320	.0152	.00324	.00499	.00092
Average.....		.7944	.9201	.0680	.0457	.0372	.00148	.00378	.0158	.00335	.00644	.00122
VI Corn; skim milk	1	.8139	.8938	.0662	.0478	.0324	.00124	.00376	.0135	.00337	.00746	.00125
	2	.7955	.9116	.0707	.0604	.0404	.00158	.00422	.0198	.00321	.00543	.00121
	3	.8068	.9232	.0647	.0513	.0389	.00116	.00309	.0169	.00321	.00467	.00112
	4	.8064	.9273	.0680	.0386	.0397	.00142	.00369	.0151	.00439	.00819	.00113
	5	.8156	.9298	.0608	.0581	.....	.00126	.00381	.0147	.00338	.00478	.00100
Average.....		.8076	.9171	.0661	.0512	.0379	00133	.00371	.0160	.00351	.00611	.00114

THE DEVELOPMENT OF THE BONES

Table VIII, p. 127, records data concerning the development of the skeleton as a whole, and of the femora and tibiae. Lots 5 and 6, receiving tankage and skim milk, respectively, had the largest proportion of bone to gross-dressed carcass, except for Lots 1 and 2, receiving corn alone and corn and soy beans, respectively, in which latter cases the higher proportion of bone to gross-dressed carcass was due not to superior development of bone but to inferior nourishment of other tissues.

The ash in the skeleton is shown to be a larger percentage of the same in the tankage and skim milk lots than in others. Among the several lots, the only one in which the calcium constituted as large a proportion of the ash as in the check lot is the lot which received tankage. Since the variation of phosphorus and magnesium in the ash is not reciprocal to the variation of calcium, we must conclude that there have been variations in the proportions of carbonate and phosphate. The proportions of calcium, magnesium and phosphorus in the ash appear not to be constant, but to be variable, to a certain extent, in accord with the food.

The ash per gram of the bones, and the breaking strength of the bones, is shown to vary together and in the following order, the maximum being mentioned first:

Lot	Ration
6.	Corn; skim milk
5.	Corn; tankage
3.	Corn; linseed oil meal
1.	Corn alone
4.	Corn; wheat middlings
2.	Corn; soy beans

The low breaking strength of the bones shows that in spite of the use of milk and tankage, and the free access which the pigs had to bone flour throughout the period of their growth, previous to the experiment, the bones produced were not nearly so strong as are the bones of pigs raised on pasture. It seems quite possible that exercise, as well as food, has its effect to strengthen the bones through inducing an added avidity of the osteogenic cells for bone salts.

In connection with the bone data the photographs on pages 148 and 149 are of interest. The three ribs figured on p. 149 are from Pig 2, Lot 1 (corn alone); the femur on the right is from Pig 1, Lot 2 (soy beans), and the femur on the left from Pig 5 of the same lot. The abnormal character of these femora is reflected in the weight, ash and breaking strength, as in Table VIII, p. 127. These bones broke and healed during the course of the experiment. In structure they were conspicuously spongy.

TABLE VIII. DATA CONCERNING DEVELOPMENT OF BONES

Lot and ration	Pig No.	Total weight of skeleton Kg.	Percent skeleton in gross dressed carcass	Moisture in skeleton Percent	Protein in skeleton Percent	Fat in skeleton Percent	Lecithin in skeleton Percent	Ash in skeleton Percent	Ash in fat- and water-free skeleton Percent	Calcium in ash Percent	Phosphorus in ash Percent	Magnesium in ash Percent	Weight of femur Grams	Ash per gram of femur Grams	Breaking strength of femur Pounds	Weight of tibia Grams	Ash per gram of tibia Grams	Breaking strength of tibia Pounds
VII Check lot	1	2.890	8.72	.....	.....	.....	.....	...	.....	.....	.....	....	..	....	279.5	....	....	294.5
	2	4.658	10.12	.....	.....	.....	.....	.....	.....	....	....	....	..	....	309.5	....	....	329.5
	3	3.646	9.81	.....	. .	.....	.....	.....	.....	.....	.....	....	..	....	365.0	....	....	406.0
	4	5.246	9.07	.....	.....	. .	.....	.....	.....	....	.....	....	.....	...	401.5	....	....	390.0
	5	4.493	9.75	.....	..	...	.....	.....	.....	.....	.....	....	.....	....	294.5	....	....	297.5
Average...		4.187	9.49	44.3900	18.6188	17.9600	0.0098	20.0300	53.20	38.27	18.04	1.02	... .	....	330.0	....	....	343.5
I Corn	1	5.491	6.82	.....	.....	....	.....	.....	.....	.....	.....	...	199.0	.177	376.0	115.5	.235	364.0
	2	4.475	6.67	....	.... .	.....	....	.....	....	....	.....	....	164.0	.196	329.0	104.0	.237	320.0
	3	3.773	6.76	.....	.. .	.....	....	.....	.....	.....	.....	....	137.5	.211	346.0	82.5	.258	319.5
	4	3.839	5.78	....	.....	.....	.....	.....	.....	.....	.....	....	144.0	.206	323.0	90.0	.243	341.0
	5	3.703	9.02	....	....	.....	.....	.....	.....	.....	.....	....	144.0	.200	333.0	90.0	.233	306.0
Average...		4.256	7.01	39.6900	18.0500	22.0600	0.0071	20.3940	53.32	37.66	17.87	1.06	157.7	.198	341.0	96.4	.241	330.1
II Corn; soy beans	1	4.243	7.79	.....	....	.....	. ...	.. .	.....	.....	.....	....	252.0	.061*	243.0	85.0	.341*	188.5
	2	4.514	6.43	.....	.....	.....	.....	.....	... .	.....	.....	....	160.0	.197	296.0	96.0	.237	365.0
	3	3.597	6.17	.....	....	.. .	.....	.....	.....	... ..	.....	....	143.0	.203	331.0	88.0	.259	348.0
	4	4.075	6.28	.....	.....	...	.....	.....	....	.....	.....	....	152.0	.201	298.0	96.0	.242	325.5
	5	4.566	8.19	.....	.....	.....	.... .	.....	.....	.....	.....	....	308.0	.165	390.0	90.0	.201	247.0
Average...		4.199	6.97	40.8300	20.1313	21.8100	0.0095	19.2560	51.54	37.36	17.80	0.94	203.0	.191	312.0	91.0	.235	294.8
III Corn; linseed oil meal	1	4.233	6.63	.....	.....	.....	.....	.....	.....	.....	.....	....	148.0	.197	317.5	96.0	.220	337.0
	2	5.581	6.90	.....	.....	.....	.....	.....	.....	.....	.....	....	209.0	.200	342.0	131.0	.234	389.0
	3	3.792	6.12	.....	.....	.....	.....	.....	.....	.....	.....	....	140.5	.243	412.5	85.0	.267	366.0
	4	3.898	6.68	.....	.....	.....	.....	.....	.....	.....	.....	....	134.0	.204	326.0	84.0	.230	284.5
	5	4.293	5.04	.....	.....	.....	.....	.....	. ...	.....	.....	....	147.0	.223	339.0	85.0	.283	355.0
Average...		4.359	6.27	37.7900	18.0000	19.6500	0.0091	20.5020	48.17	37.98	18.21	1.10	155.7	.213	347.4	96.0	.247	346.3

*Not included in average.

TABLE VIII. DATA CONCERNING DEVELOPMENT OF BONES—Concluded

Lot and ration	Pig No.	Total weight of skeleton Kg.	Percent skeleton in gross dressed carcass	Moisture in skeleton Percent	Protein in skeleton Percent	Fat in skeleton Percent	Lecithin in skeleton Percent	Ash in skeleton Percent	Ash in fat- and water-free skeleton Percent	Calcium in ash Percent	Phosphorus in ash Percent	Magnesium in ash Percent	Weight of femur Grams	Ash per gram of femur Grams	Breaking strength of femur Pounds	Weight of tibia Grams	Ash per gram of tibia Grams	Breaking strength of tibia Pounds
IV	1	5.371	7.87	.....	....	.....	.....	.....	.....	.....	.....	....	167.0	.186	307.0	115.0	.215	284.5
	2	4.131	6.41	.....	....	.....	.....	.....	.....	.	.....	....	150.0	.213	348.0	97.0	.245	290.0
Corn; wheat middlings	3	4.911	6.67	....	.....	....	.....	.....	.....	.....	.....	....	173.0	.218	400.0	115.0	.242	410.0
	4	5.157	5.99	.....	...	.....	..	.....	.....	.....	.....	....	178.0	.156	275.5	114.0	.202	274.5
	5	3.915	5.79	.....	.....	.. .	....	....	.....	.....	.....	....	139.0	.213	.....	92.0	.244	331.0
Average...		4.697	6.55	45.5200	20.5000	14.6400	0.0116	19.0330	47.77	36.70	18.01	1.14	161.0	.197	332.6	107.0	.230	318.0
V	1	4.850	6.02	.....	.....	.....	. ....	.....	.....	.....	.....	....	166.0	.255	534.5	105.0	.298	502.0
	2	4.879	6.89	. .	....	.....	.....	....	.....	.....	.....	....	171.0	.250	411.0	114.0	.284	485.0
Corn; tankage	3	4.276	6.85	.....	.....	.....	..	.....	.....	.....	.....	. ..	154.0	.214	411.0	96.0	.251	320.0
	4	4.066	7.61	.....	...	.....	.....	.....	.....	.....	.....	....	145.0	.202	355.0	88.0	.246	302.0
	5	5.045	6.64	.....	.....	.....	.....	.....	.....	.....	. ...	....	179.0	.230	394.0	118.0	.258	475.0
Average...		4.623	6.80	38.3100	20.3375	19.1400	.....	23.8160	55.97	38.36	18.16	0.94	163.0	.230	421.1	104.0	.267	417.0
VI	1	5.441	6.62	....	.....	.....	.....	.....	.....	.....	.....	....	189.0	.251	434.5	117.0	.300	465.0
	2	4.693	7.07	....		...	.. ..	... .	.....	.....	... ..	....	166.0	.246	407.0	101.0	.282	427.0
Corn; skim milk	3	5.850	6.47	....	.....	.	..	.....	.....	.. ..	.....	....	190.5	.252	464.0	126.0	.284	516.0
	4	4.926	6.80	. ..	.....	.....	.....	.....	.....	.....	.....	...	167.0	.238	397.0	105.0	.272	419.0
	5	5.218	6.08	.....	....	....	..	.....	.....	.....	.....	....	187.0	.240	482.0	109.0	.292	475.0
Average...		5.226	6.61	41.5700	20.6438	15.6300	0.0075	24.1790	56.49	37.91	17.95	0.92	179.9	.245	436.9	112.0	.286	460.0

The bones figured on p. 148 are all from Lot 4 (wheat middlings). The fractured scapula and the eight ribs below are all from one-half of Pig 1. Of the ribs in the upper row the eight to the left are from Pig 3; the two on the right are from Pigs 2 and 5.

All told there were in Pigs 2 and 5 of Lot 1 (corn alone) 7 ribs which appeared to have been broken. Pigs 1 and 5 of Lot 2 (soy beans) had the broken femora as figured, and many broken dorsal spines on the vertebrae. In Lot 4 (wheat middlings), Pig 1 had a broken scapula and 12 broken ribs; Pig 2, one broken rib; Pig 3, 8 broken ribs and many ribs enlarged at the distal ends; Pig 4, knobs on ends of ribs, and Pig 5, 1 broken rib and one with an enlarged end.

TABLE IX. ANALYSIS OF BONE—Percent, Fresh Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Calcium	Magnesium	Phosphorus, total	Phosphorus, lecithin
I	Corn	39.6900	18.0500	22.0600	20.3940	7.6810	0.2171	3.6450	0.0071
II	Corn; soy beans	40.8300	20.1313	21.8100	19.2560	7.1940	0.1801	3.4270	0.0095
III	Corn; linseed oil meal	37.7900	18.0000	19.6500	20.5020	7.7860	0.2249	3.7330	0.0091
IV	Corn; wheat middlings	45.5200	20.5000	14.6400	19.0330	6.9850	0.2164	3.4270	0.0116
V	Corn; tankage	38.3100	20.3375	19.1400	23.8160	9.1350	0.2244	4.3260	.....
VI	Corn; skim milk	41.5700	20.6438	15.6300	24.1790	9.1670	0.2225	4.3390	0.0075
VII	Check lot*	44.3900	18.6188	17.9600	20.0300	7.6660	0.2044	3.6140	0.0098

*Killed at beginning of experiment.

TABLE X. ANALYSIS OF BONE
All Figures Except Moisture on the Dry Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Calcium	Magnesium	Phosphorus, total	Phosphorus, lecithin
I	Corn	39.6900	29.4405	35.9811	33.2637	12.5281	0.3541	5.9452	0.0116
II	Corn; soy beans	40.8300	34.0228	36.8599	32.5435	12.1582	0.3044	5.7918	0.0161
III	Corn; linseed oil meal	37.7900	28.9342	31.5866	32.9561	12.5157	0.3615	6.0006	0.0146
IV	Corn; wheat middlings	45.5200	37.6285	26.8722	34.9358	12.8212	0.3972	6.2904	0.0213
V	Corn; tankage	38.3100	32.9673	31.0261	38.6059	14.8079	0.3638	7.0125	.....
VI	Corn; skim milk	41.5700	35.3308	26.7500	41.3811	15.6889	0.3808	7.4260	0.0128
VII	Check lot*	44.3900	33.4810	32.2963	36.0187	13.7853	0.3676	6.4988	0.0176

*Killed at beginning of experiment.

The above data should make it very clear that rations of cereals alone do not produce normal bones, a fact which directs especial attention to the roughage, milk and supplementary concentrates of the ration. This is a matter of slight importance to the man who is feeding for market, hogs which have been raised on pasture; it is a matter of much importance to the man who is trying to raise pigs, especially breeding stock which he wishes to grow rapidly, confined in small lots.

Tables IX and X, page 129, give the analyses of the whole skeleton of the pigs in the several lots, Table IX being on the fresh basis and Table X on the water-free basis. Table X shows that the ether extract of the skeletons of the corn and of the soy bean lots (Nos. 1 and 2) were the only ones higher in this constituent than the check lot. The ash in the skeletons of these lots was low. Corn and soy beans are very poor in bone food. The calcium and phosphorus are shown to have been lower than in the check lot in the skeletons of all lots except those receiving tankage and milk. Magnesium, on the other hand, was higher in the wheat middlings lot than in the check lot. This ration was especially rich in magnesium.

THE COMPOSITION OF THE FLESH

Tables XI and XII, page 131, set forth the analyses of the total flesh of the carcasses, including the leaf fat. Table XI, on the fresh basis, shows that the corn lot, No. 1, had less moisture, protein and ash, and more fat in the flesh than did any of the lots which received the supplemented rations—a direct effect of the composition of the food. At the opposite extreme stands the lot which received skim milk with the corn (No. 6), this one containing the maximum of moisture and protein, and the minimum of fat in the flesh.

There appears to be marked variation in the content of the flesh in the mineral constituents; for instance, sodium varies between 0.0635 and 0.1036 percent, among the lots which were fed, that is, excluding the check lot. On the same basis, potassium varies between 0.1888 and 0.2419 percent; calcium between 0.0217 and 0.0319 percent; magnesium between 0.0146 and 0.0188 percent; sulphur between 0.1289 and 0.1799 percent; chlorine between 0.0353 and 0.0679 percent and phosphorus between 0.1227 and 0.1506 percent. There is also much variation in inorganic phosphorus and in lecithin, especially the latter (0.0147-0.0273 percent).

TABLE XI. ANALYSIS OF FLESH—Percent, Fresh Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus, total	Phosphorus, inorganic	Phosphorus, lecithin
I	Corn	31 3200	8.9375	59.5300	0.5230	0.0680	0.1297	0.0157	0.0100	0.0885	0.0352	0.0843	0.0467	0.0101
II	Corn; soy beans	36 2200	9.6250	54.3500	0.6050	0.0661	0.1413	0.0172	0.0111	0.1041	0.0266	0.0958	0.0605	0.0174
III	Corn; linseed oil meal	33.7500	9.1250	57.4600	0.5650	0.0421	0.1398	0.0155	0.0110	0.1056	0.0374	0.0874	0.0499	0.0139
IV	Corn; wheat middlings	35.3200	9.4375	55.3800	0.5750	0.0528	0.1358	0.0192	0.0116	0.1031	0.0439	0.0908	0.0596	0.0162
V	Corn; tankage	33.9400	9.1375	57.9200	0.5500	0.0544	0.1369	0.0211	0.0106	0.1000	0.0233	0.0862	0.0561	0.0167
VI	Corn; skim milk	37.3000	10.5188	52.8600	0.5930	0.0589	0.1517	0.0136	0.0118	0.1128	0.0297	0.0944	0.0632	0.0148
VII	Check lot*.	40.8500	10.6875	48.3500	0.6490	0.0719	0.1730	0 0125	0.0136	0.1126	0.0450	0.1041	0.0703	0.0194

*Killed at beginning of experiment.

TABLE XII. ANALYSES OF FLESH
All Figures Except Moisture on the Dry Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus, total	Phosphorus, inorganic	Phosphorus, lecithin
I	Corn	31.3200	13.0133	86.6773	0.7615	0.0990	0.1888	0.0229	0.0146	0.1289	0.0513	0.1227	0.0680	0.0147
II	Corn; soy beans	36.2200	15.0909	85.2148	0.9485	0.1036	0.2215	0.0270	0.0174	0.1632	0.0417	0.1502	0.0949	0.0273
III	Corn; linseed oil meal	33.7500	13.7736	86.7321	0.8528	0.0635	0.2110	0.0234	0.0166	0.1594	0.0565	0.1319	0.0753	0.0210
IV	Corn; wheat middlings	35.3200	14.5911	85.6215	0.8890	0.0816	0.2100	0.0297	0.0179	0.1594	0.0679	0.1404	0.0921	0.0251
V	Corn; tankage	33.9400	13.8321	87.6779	0.8326	0.0823	0.2072	0.0319	0.0160	0.1514	0.0353	0.1305	0.0849	0.0253
VI	Corn; skim milk	37.3000	16.7764	84.3062	0.9458	0.0939	0.2419	0.0217	0.0188	0.1799	0.0474	0.1506	0.1008	0.0236
VII	Check lot*	40.8500	18.0685	81.7413	1.0972	0.1216	0.2925	0.0211	0.0230	0.1904	0.0761	0.1760	0.1189	0.0328

*Killed at beginning of experiment.

THE COMPOSITION OF THE BLOOD

The analyses of the blood are in Tables XIII and XIV on page 133. Among the more notable points in the tables are the high moisture and ash content of the blood of Lot 1 (corn alone), and the high nitrogen content of the blood in Lots 3 (linseed oil meal), 5 (tankage) and 6 (skim milk). The analyses of the ash also signify characteristic differences in the several lots.

THE COMPOSITION OF THE BRAIN

The brain analyses are in Tables XV and XVI, page 134. Among all the tissues one would, as little as in any, expect an appreciable influence on the composition of the brain through the effects of common foods. Without individual analyses it would be impossible to judge of the significance of such variations as are here noted. The ether extract of the brain in the wheat middlings lot, No. 4, appears to be significantly lower than all others. In general, little variation is manifest.

THE COMPOSITION OF THE SKIN

The skin (Table XVII, p. 135) was analyzed only to complete the accounting for the carcasses, since it adheres so closely to the subcutaneous fat that an accurate anatomical separation is not practicable.

THE COMPOSITION OF THE ENTIRE GROSS-DRESSED CARCASSES

The final accounting for the total protein, fat and ash of the gross-dressed carcass and of the proportions of protein, fat and ash in flesh, bones and carcass, is set forth in Table XVIII, p. 135. These data show that there is a specific effect of the ration on the proportions of the main tissue components. In the order of decreasing proportion of protein in the flesh the several lots rate as follows:

Lots	Rations	Protein	:	Ether extract
7.	Check lot	1	:	4.52
6.	Corn; skim milk	1	:	5.03
2.	Corn; soy beans	1	:	5.65
4.	Corn; middlings	1	:	5.87
3.	Corn; linseed oil meal	1	:	6.30
5.	Corn; tankage	1	:	6.34
1.	Corn	1	:	6.66

TABLE XIII. ANALYSIS OF BLOOD—Percent, Fresh Basis

Lot	Moisture	Nitrogen	Protein	Ether extract	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus, total	Phosphorus, lecithin	Phosphorus, inorganic
I	81.8511	3.0502	19.0639	.1172	1.0123	.2079	.1843	.0090	.0063	.1229	.2107	.0548	.....	0.0195
II	80.1150	2.9187	18 2416	.1464	.9684	.2160	.1894	.0087	.0058	.1276	.2395	.0537	.0119	0.0185
III	79.5965	3.1743	19.8394	.1836	.9494	.2049	.1857	.0081	.0065	.1291	.2209	.0589	.0089	0.0196
IV	80.2316	2.9471	18.4193	.1100	.9454	.1980	.1890	.0078	.0065	.1218	.2258	.0542	.0093	0.0174
V	79.5260	3.3004	20.6275	.1573	.9374	.2187	.1800	.0092	.0066	.1172	.2142	.0535	.0130	0.0157
VI	78.9948	3.2899	20.5616	.1372	.9659	.2084	.1881	.0089	.0060	.1301	.2193	.0522	.0099	0.0171
VII	81.2885	2.9914	18.6963	.1119	.9208	.2069	.1880	.0091	.0057	.1175	.2172	.0534	.0098	0.0172

TABLE XIV. ANALYSIS OF BLOOD
All Figures Except Moisture on the Dry Basis

Lot	Ration	Moisture	Ash	Sodium	Potassium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus, total	Phosphorus, inorganic	Phosphorus, lecithin
I	Corn.....	81.8511	5.5777	1.1455	1.0158	0.0494	0.0347	0.6770	1.1607	0.3020	0.1074	.....
II	Corn; soy beans..... .	80.1150	4.8701	1.0861	0.9524	0.0438	0.0294	0.6415	1.2045	0.2700	0.0930	0.0597
III	Corn; linseed oil meal... .	79.5965	4.6532	1.0042	0.9100	0.0398	0.0319	0.6326	1.0825	0.2887	0.0961	0.0436
IV	Corn; wheat middlings... .	80.2316	4.7822	1.0015	0.9560	0.0392	0.0329	0.6162	1.1423	0.2740	0.0880	0.0470
V	Corn; tankage..... .	79.5260	4.5783	1.0679	0.8791	0.0450	0 0323	0.5726	1.0464	0.2615	0.0767	0.0637
VI	Corn; skim milk.....	78.9948	4.5982	0.9922	0.8954	0.0425	0.0288	0.6192	1.0438	0.2484	0.0814	0.0470
VII	Check lot*.....	81.2885	4.9212	1.1057	1.0046	0.0487	0.0306	0.6279	1.1608	0.2854	0.0919	0.0524

*Killed at beginning of experiment.

TABLE XV. ANALYSIS OF BRAIN—Percent, Fresh Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Phosphorus, total	Phosphorus, inorganic	Phosphorus, lecithin
I	Corn	77.7500	10.2813	9.5400	1.5110	0.3203	0.0764	0.2260
II	Corn; soy beans	77.4100	10.3625	9.6600	1.5446	0.3332	0.0803	0.2360
III	Corn; linseed oil meal	77.5500	10.5188	9.3500	1.4864	0.3300	0.0780	0.2340
IV	Corn; wheat middlings	78.2300	10.0438	7.7330	1.5146	0.3207	0.0752	0.2040
V	Corn; tankage	77.9600	10.4563	9.0500	1.5046	0.3228	0.0777	0.2310
VI	Corn; skim milk	77.8900	10.0625	9.1400	1.4922	0.3277	0.0796	0.2350
VII	Check lot*	79.2100	9.8750	8.5300	1.4833	0.3201	0.0829	0.2160

*Killed at beginning of experiment.

TABLE XVI. ANALYSIS OF BRAIN
All Figures Except Moisture on the Dry Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash	Phosphorus, total	Phosphorus, inorganic	Phosphorus, lecithin
I	Corn	77.7500	46.2081	42.8764	6.7910	1.4395	0.3434	1.0157
II	Corn; soy beans	77.4100	45.8721	42.7623	6.8375	1.4750	0.3555	1.0447
III	Corn; linseed oil meal	77.5500	46.8543	41.6481	6.6209	1.4699	0.3474	1.0423
IV	Corn; wheat middlings	78.2300	46.1360	35.5214	6.9573	1.4731	0.3454	0.9371
V	Corn; tankage	77.9600	47.4424	41.0617	6.8267	1.4647	0.3525	1.0481
VI	Corn; skim milk	77.8900	45.5111	41.3388	6.7490	1.4821	0.3600	1.0629
VII	Check lot*	79.2100	47.4988	41.0293	7.1347	1.5397	0.3987	1.0390

*Killed at beginning of experiment.

TABLE XVII. ANALYSIS OF SKIN—Percent, Fresh Basis

Lot	Ration	Moisture	Protein	Ether extract	Ash
I	Corn	58.460	31.9313	10.5200	0.6558
II	Corn; soy beans	60.8900	31.3125	9.5500	0.6297
III	Corn; linseed oil meal	60.8000	30.6375	11.7200	0.6572
IV	Corn; wheat middlings	62.9400	29.5690	8.6900	0.7002
V	Corn; tankage	62.8400	28.8375	9.3500	0.6619
VI	Corn; skim milk	65.7500	27.4625	8.0700	0.6486
VII	Check lot*	60.9000	27.6875	12.6100	0.5919

*Killed at beginning of experiment.

TABLE XVIII. TOTAL CONSTITUENTS IN GROSS-DRESSED CARCASSES, AND PROPORTIONS OF PROTEIN, ETHER EXTRACT AND ASH

Lot No.	Rations	Tissue	Protein Kilos	Ether extract Kilos	Ash Kilos	Ratio of protein, ether extract and ash
I	Corn	Flesh	4.8509	32.3105	0.2839	1 : 6.660 : 0.059
		Skin	0.9401	0.3097	0.0193	
		Bone	0.7682	0.9389	0.8680	1 : 1.220 : 1.130
		Total	6.5592	33.5591	1.1712	1 : 5.120 : 0.178
II	Corn; soy beans	Flesh	5.1229	28.9278	0.3220	1 : 5.650 : 0.063
		Skin	0.7922	0.2416	0.0159	
		Bone	0.8453	0.9158	0.8086	1 : 1.083 : 0.957
		Total	6.7604	30.0852	1.1465	1 : 4.450 : 0.170
III	Corn; linseed oil meal	Flesh	5.6477	35.5637	0.3497	1 : 6.300 : 0.062
		Skin	1.0643	0.4072	0.0228	
		Bone	0.7846	0.8565	0.8937	1 : 1.092 : 1.139
		Total	7.4966	36.8274	1.2662	1 : 4.910 : 0.169
IV	Corn; wheat middlings	Flesh	5.8946	34.5898	0.3591	1 : 5.870 : 0.061
		Skin	1.1751	0.3453	0.0278	
		Bone	0.9625	0.6873	0.8936	1 : 0.714 : 0.928
		Total	8.0322	35.6224	1.2805	1 : 4.430 : 0.159
V	Corn; tankage	Flesh	5.4730	34.6918	0.3294	1 : 6.340 : 0.060
		Skin	0.9473	0.3071	0.0217	
		Bone	0.9402	0.8848	1.1010	1 : 0.941 : 1.171
		Total	7.3605	35.8837	1.4521	1 : 4.880 : 0.197
VI	Corn; skim milk	Flesh	7.1916	36.1399	0.4054	1 : 5.030 : 0.056
		Skin	1.2344	0.3627	0.0292	
		Bone	1.0788	0.8168	1.2636	1 : 0.757 : 1.171
		Total	9.5048	37.3194	1.6982	1 : 3.930 : 0.179
VII	Check lot; not fed	Flesh	3.8160	17.2634	0.2317	1 : 4.520 : 0.061
		Skin	0.8782	0.4000	0.0188	
		Bone	0.7796	0.7520	0.8387	1 : 0.965 : 1.076
		Total	5.4738	18.4154	1.0892	1 : 3.360 : 0.199

In order of decreasing proportion of ash to protein in the bones the several lots rate as below:

Lots	Rations	Protein	:	Ash
6.	Corn; skim milk	1	:	1.171
5.	Corn; tankage	1	:	1.171
3.	Corn; linseed meal	1	:	1.139
1.	Corn	1	:	1.130
7.	Check lot	1	.	1.076
2.	Corn; soy beans	1	:	0.957
4.	Corn; middlings	1	.	0.928

That the skim milk and tankage rations should produce bones containing the maximum proportions of ash to protein is in harmony with all of the evidence, including our own balance experiments; and that the soy bean and wheat middlings rations should produce bones having less ash in proportion to protein than any others in the experiment is also consistent with other evidence as it has come to us, especially with that presented in the photographs on pages 148 and 149.

Considering the gross-dressed carcasses as a whole, flesh, skin and bone together, the lots rank in the following order of decreasing proportion of protein to fat.

Lots	Rations	Protein	:	Ether extract	:	Ash
7.	Check lot	1	:	3.36	:	0.199
6.	Corn; skim milk	1	:	3.93	:	0.179
4.	Corn; middlings	1	:	4.43	:	0.159
2.	Corn; soy beans	1	:	4.45	:	0.170
5.	Corn; tankage	1	:	4.88	:	0.197
3.	Corn; linseed meal	1	:	4.91	:	0.169
1.	Corn	1	:	5.12	:	0.178

In considering the specific effects of the rations involved in this work it is well to bear in mind that the comparative results are determined by the proportions in which the foods composing these rations were fed, and are characteristic, therefore, not of the supplements as such, but of the corn and supplements together, in these particular proportions; thus, with a larger percentage of tankage in the ration it would be possible very greatly to increase the proportion of ash to other body constituents above the figure here reported.

The above data indicate that there are important differences in the capacities of digestible protein from these several sources to contribute to the proteid increase of growing swine; and especially that a pound of digestible milk protein has a value for purposes of growth which is greater than that possessed by the digestible protein of soy beans, linseed oil meal, wheat middlings and tankage.

HISTOLOGICAL ANALYSES OF THE BLOOD

During the last week of the experiment blood samples were taken from each pig for an estimation of the haemoglobin and a differential count of the corpuscles. In order to have conditions as nearly uniform as possible, one lot per day was sampled, during six days, at exactly the same hour. This work occasioned no marked disturbance to the animals, except in a very few cases, but the live weights for this week were not consistent. While it would be desirable to have several blood counts from each individual one should bear in mind the fact that such work disturbs the live weights and requires the lapse of some days for these weights to become readjusted before they can be considered reliable and significant.

In consideration of the transitory character of blood conditions it is obvious that uniform consumption of food by the pigs is essential to the most significant data as indicating the specific effects of the kind of food on these blood conditions. In this experiment the consumption of food was not according to schedule in some of the lots, and there is evidence that these irregularities affected the results of the blood analyses in such ways as to reduce their significance in relation to the kinds of food involved. Thus in Lot 4, Pig No. 1, which was eating poorly at the time the blood test was made, had the least haemoglobin, the fewest red and white corpuscles, a small percent of polymorphs and a high percent of lymphocytes, as compared with other pigs which were eating more liberally. Pig 3 was also eating comparatively little food. This pig's blood was high in haemoglobin and red corpuscles, but low in white corpuscles and polymorphs, while it contained the maximum number of lymphocytes. In Lots 3, 5 and 6, where the food consumption was more nearly uniform, there was less individual variation.

In relating the blood analyses to the composition of the rations the following conditions seem to be more certainly characteristic than others: In Lot 1 (corn) the low haemoglobin content, the maximum percentage of polymorphs and minimum percentage of lymphocytes; in Lot 5 (tankage) the uniformly high haemoglobin content; in Lot 6 (milk) the large number of white corpuscles; and in Lots 3 (linseed) and 6 (milk) the low percentage of polymorphs and high percentage of lymphocytes.

The data have a further value as furnishing a normal basis for use in the interpretation of later investigations.

TABLE XIX. HISTOLOGICAL ANALYSIS OF BLOOD
By Dr. H. N. Mateer

Lot and ration	Pig No.	Haemoglobin Percent	Corpuscles, red	Corpuscles, white	Percentage distribution of leucocytes			
					Polymorphonuclear	Lymphocytes	Mononuclear and transitional	Eosinophiles
I Corn	1	95	9,376,000	25,200	43	45	6	6
	2	94	8,552,000	22,480	31	62	4	3
	3	90	7,472,000	25,000	52	43	4	1
	4	103	9,008,000	19,880	45	51	3	1
	5	95	8,560,000	21,920	39	54	5	2
Average..		95.4	8,593,600	22,896	42.0	51.0	4.5	2.6
II Corn; soy beans	1	95	8,104,000	30,600	37	61	1	1
	2	105	8,752,000	25,400	48	40	5	7
	3	108	8,784,000	23,920	40	56	3	1
	4	90	7,712,000	12,480	28	69	0	3
	5	102	8,104,000	19,600	33	63	2	2
Average...		100.0	8,291,200	22,400	37.2	57.8	2.2	2.8
III Corn; linseed oil meal	1	100	7,616,000	17,200	29	61	6	1
	2	95	7,912,000	21,680	24	71	3	2
	3	90	8,304,000	23,120	43	54	2	1
	4	94	9,128,000	31,480	26	70	1	3
	5	110	9,080,000	24,600	20	75	1	4
Average...		97.8	8,408,000	23,616	28.4	66.2	2.6	2.2
IV Corn; wheat middlings	1	80	6,654,000	13,120	25	67	4	4
	2	106	8,112,000	25,800	49	47	2	2
	3	105	8,550,000	13,880	14	78	6	2
	4	95	8,976,000	29,320	39	41	10	10
	5	93	7,352,000	22,520	42	50	6	2
Average...		95.8	7,928,800	20,930	33.8	56.6	5.6	4.0
V Corn; tankage	1	100	8,904,000	23,360	23	69	1	6
	2	103	9,104,000	24,000	22	70	1	6
	3	103	12,152,000	18,880	46	47	0	7
	4	102	7,400,000	22,400	45	48	3	4
	5	101	7,776,000	27,000	29	44	8	19
Average...		101.8	9,067,200	23,128	33.0	55.6	2.6	8.4
VI Corn; skim milk	1	102	8,600,000	25,480	28	64	6	2
	2	101	9,016,000	31,880	33	65	2	0
	3	90	8,512,000	26,200	22	57	6	15
	4	96	8,750,000	24,600	24	62	5	9
	5	98	8,860,000	25,400	32	62	1	5
Average...		97.4	8,747,600	26,712	27.8	62.0	4.0	6.0

ESTIMATIONS OF CATALASE

In the course of this experiment there have been made many chemical estimations which we are unable definitely to relate to the physiological processes of the animal; for instance the ash analyses of the flesh and blood. Certain of these data will doubtless be found

of value in connection with metabolism investigations, but such estimations of the composition of the working parts leave us desiring more significant measures of physiological capacities, as gauged by quantitative valuations of products of vital activity. In this connection a series of estimations of the capacities of the organs and tissues of animals to accomplish, through the activity of their enzymes, the main types of chemical change in the state of matter that are characteristic of the normal functions of these parts in life, promises to contribute much more toward our knowledge of the specific effects of foods in the life of animals than can ever be learned through a study of the composition of the body. An extensive series of such estimations was contemplated as a part of this experiment, but this work was not completed, on account of the failure of our water supply and consequently of the refrigerating plant. A beginning, however, was made, in such a study, in a series of estimations of catalase in several of the important tissues and organs of the body.

Catalase is a vital enzyme which is especially abundant in blood, and is supposed to be present in all tissues. Its activity decreases greatly in certain pathological conditions, and is measured by the power of the enzyme present in a given weight of tissue to split off oxygen from hydrogen peroxide. The theory of Jolles and Oppenheim that it is the rôle of catalase in the blood to eliminate oxygen from oxyhaemoglobin is one of many which have been advanced in explanation of its function.

Catalase was estimated in the composite samples of flesh, blood, brain, liver, kidney and spleen. The very high content of the blood, and the low content of the flesh, in catalase, suggests that the catalase content of the latter is likely to be influenced by the blood which it normally contains. It would be very desirable to remove the blood from tissues in preparing them for catalase estimation. We do not know of any method for accomplishing this purpose which could be used in connection with the routine of just such an investigation as this one. We suspect that catalase estimations of the highest significance will require complete preliminary exsanguination of the living animal. That the flesh of Lot 6 (skim milk) should have no catalase suggests that all of the catalase of the flesh is due to blood contained therein, and possibly that the skim milk has such an effect on the musculature of the blood vessels as results in more complete bleeding out than occurs under the influence of other foods. It is well-known that milk in the diet produces especially light-colored flesh in calves and poultry.

In the brain the catalase varies comparatively little. It is of interest, in connection with the results from muscle, that the catalase of the brain of Lot 6 (skim milk) should be lower than in other lots.

In the blood the catalase seems significantly lower in Lots 1 and 5, those containing the largest proportions of corn, than in others, and that Lot 6 (skim milk) should contain practically as much catalase in the blood as any other lot. This last observation would imply that the low catalase values for brain and muscle in Lot 6 are due not to a general condition in these animals but to special conditions within those particular tissues.

The catalase of the liver of Lots 4 and 5 appears to be significantly low, while in the kidneys there are probably no significant differences. The catalase in the spleens varies rather widely, from 8.06 (cc. of oxygen liberated per gram of substance) in Lot 5 to 15.07 in Lot 1.

TABLE XX. COMPARATIVE ESTIMATIONS OF CATALASE IN ORGANS AND TISSUES OF SWINE

Lot No.	Ration	Cubic centimeters oxygen liberated per gram sample					
		Flesh	Blood	Brain	Liver	Kidney	Spleen
I	Corn	1.3920	206.9200	9.2720	125.24	110.24	15.07
II	Corn; soy beans	1.3840	230.0400	7.6960	129.32	109.44	13.69
III	Corn; linseed oil meal	1.3840	225.4400	9.6720	126.96	107.40	11.92
IV	Corn; wheat middlings	0.4960	225.0000	8.0880	116.60	106.92	15.94
V	Corn; tankage	0.3520	216.8000	9.2160	114.88	106.56	8.06
VI	Corn; skim milk	0.0000	229.6800	7.2480	121.48	109.16	8.77
VII	Check lot*	1.2080	223.1600	....	126.04	105.40	9.30

*Killed at beginning of experiment.

EXAMINATION OF THE MEAT

One-half of each carcass was used for an examination of the flesh, first to note effects of the feeding on the proportion of fat and muscular tissue, and second to determine the effects of the feeding on the acceptability of the cured and cooked meat. In the latter relation our interest was especially to ascertain whether the marked differences often found in the palatability of the cured pork as purchased in the market are due in part to methods of feeding or entirely to methods of curing.

In the physical examination of the bacon the several lots rated as to hardness of the fat in the following order, the hardest being mentioned first.

Corn; skim milk
Corn; wheat middlings
Corn
Corn; linseed oil meal
Corn; tankage
Corn; soy beans

Within the several lots the hardness of the bacon, as estimated without instruments of precision, was rated as below, in order of decreasing hardness. In many cases there were not differences sufficiently pronounced to be unmistakable.

Corn; skim milk	Corn; wheat middlings	Corn	Corn; linseed oil meal	Corn; tankage	Corn; soy beans
3	4	4	5	2	2
5	5	1	4	1	4
1	3	2	2	5	1
2	1	5	1	3	5
4	2	3	3	4	3

A consideration of this arrangement of the individuals within the lots on the basis of the firmness of the bacon, in connection with a similar arrangement on the basis of live weights, reveals a similarity which suggests an essential relation.

The hardness of the fatty tissue appears to be determined by the resultant of two factors, first the fatness of the tissue, that is, the state of engorgement of the fat cells, and second the physical character of the fats present.

In the cooking test of the bacon all lots were found to be of good quality, there being no great differences between them. The bacon produced from corn alone, however, differed from that produced by the rations containing more protein by a greater tendency of the lean to shrink, thus drawing the strips out of shape. In common with the bacon produced from corn and linseed oil meal it seemed not to become crisp at so light a color as did the bacon from other lots. The bacon from corn and linseed oil meal was slightly less crisp than that from other lots; otherwise the bacon was beyond our abilities to criticize; the bacon from corn and soy beans was exceedingly good to eat, its acceptability in this relation appearing not to be less than that of others, even though this was the softest of all when in an uncooked condition. We concluded, therefore, that the cooking quality of bacon does not necessarily vary with its softness previous to cooking.

The highest quality of bacon, from the point of view of the person who eats it, is not necessarily found in that from the animals which have made either the most rapid or economical gain in weight.

or in those pigs which are in the most nearly normal state of nutrition; for instance, the pigs fed on corn alone were certainly in a very abnormal state of nutrition, but the fat of the bacon had a crisp and delicate quality, as it was eaten, which was highly satisfactory but doubtless due to an abnormal delicacy and underdevelopment of the connective tissue, coupled with a prominent deposition of fat.

A slice of each ham was cut, at a fixed point, and portions of each were broiled and eaten, for the purpose of comparing the effects of the foods on the quality of the meat. In this cooking test two methods were employed. First, similar portions of each cut were cooked, one at a time, as nearly as possible to the same condition; second, similar portions from each cut were arranged in order in a large pan, and all cooked at once under as nearly uniform conditions as could be obtained. Such a study is necessarily difficult, and without great promise, in view of the uncertain and indefinite character of the results.

The ham from each of the lots was of good quality, and there were no important differences in the palatability of the meat, though the ham from the wheat middlings lot seemed more tender than the others. In no case was there any objectionable quality in the meat. We conclude, therefore, that the important differences noted in the quality of cured pork in the market are due especially to methods of curing rather than feeding.

SUMMARY

A feeding and carcass-analysis experiment was conducted with swine in a study of the specific effects of rations on the composition of the growth produced. The rations were corn alone, and corn supplemented by soy beans, wheat middlings, linseed oil meal, tankage and skim milk. These rations were fed in quantities such as contained the same amount of digestible nutriment per unit of live weight of the pigs. The supplemented rations contained the same proportions of protein to non-nitrogenous starch-equivalent. The experiment, therefore, was in large measure a comparison of the capacities of pigs to grow on equivalent amounts of protein from different sources. Thirty-five pigs were used in 7 lots of 5 pigs each.

The capacity of digestible milk protein to cause proteid increase was shown to be greater than that of digestible protein from the vegetable foods used and from tankage.

Corn supplemented by soy beans, linseed oil meal, wheat middlings, tankage and skim milk in proportions such that the nutritive ratios of the rations are as 1:6.5 does not furnish mineral matter of the amounts and kinds requisite to maximum growth of bones.

The rations of corn alone and of corn and soy beans produced the least bone. The rations of corn supplemented by tankage and by skim milk produced the most bone. Rations of cereals alone will not produce normal growth of bone.

The lot which received corn and linseed oil meal produced the largest percentage of flesh and leaf fat (together) and the smallest percentage of bone, as related to the gross-dressed carcass, of any lot in the series.

The lots which received tankage and skim milk had the largest proportions of bone to gross-dressed carcass, except for the lots which received corn alone, and corn and soy beans, in which latter cases the higher proportion of bone to gross-dressed carcass was due not to superior development of bone but to inferior nourishment of other tissues.

The proportions of calcium, magnesium and phosphorus in the bones tends strongly to remain constant, but may be modified to a certain extent by the limitations of the food. The *amounts* of these elements in the bone, however, are susceptible of much greater modification through the composition of the food.

The ash per gram of the bones, and the breaking strength of the bones, were shown to vary together in the following order of decreasing magnitude: (1) Corn and skim milk, (2) corn and tankage, (3) corn and linseed oil meal, (4) corn alone, (5) corn and wheat middlings, and (6) corn and soy beans.

The calcium and phosphorus content of the skeleton was lower than in the check lot (killed at the beginning of the experiment) in all lots except those which received tankage and milk. The magnesium content of the skeletons of the pigs which received wheat middlings (a food very rich in magnesium) was higher than in the check lot.

The ration of corn alone produced less moisture, protein and ash, and more fat in the flesh than did any of the supplemented rations. At the opposite end of the series stands the ration of corn and skim milk, which produced the maximum of moisture and protein and the minimum of fat in the flesh.

There is marked variation in the content of the flesh and blood in the mineral constituents, apparently as determined by the food.

One-half of each carcass was cured. The foods were found to have produced marked differences in the firmness of the hams and bacon, and certain effects on their behavior in cooking; also slight effects on the acceptability of the cooked meat.

One-half of each carcass was analyzed and a complete chemical accounting made. The data show that there is a specific effect of the ration on the proportions of the main tissue components.

In the order of decreasing proportion of protein in the flesh the several lots rated as follows:

Lots	Rations	Protein	:	Ether extract
7.	Check lot	1	:	4.52
6.	Corn; skim milk	1	:	5.03
2.	Corn; soy beans	1	:	5.65
4.	Corn; middlings	1	:	5.87
3.	Corn; linseed meal	1	:	6.30
5.	Corn; tankage	1	:	6.34
1.	Corn	1	:	6.66

In the order of decreasing proportion of ash to protein in the bones the several lots rated as follows:

Lots	Rations	Protein	:	Ash
6.	Corn; skim milk	1	:	1.171
5.	Corn; tankage	1	:	1.171
3.	Corn; linseed meal	1	:	1.139
1.	Corn	1	:	1.130
7.	Check lot	1	:	1.076
2.	Corn; soy beans	1	:	0.957
4.	Corn; middlings	1	:	0.928

In the order of decreasing proportion of protein to fat in the gross-dressed carcass, as a whole, the several lots rated as follows:

Lots	Rations	Protein	:	Ether extract	:	Ash
7.	Check lot	1	:	3.36	:	0.199
6.	Corn; skim milk	1	:	3.93	:	0.179
4.	Corn; middlings	1	:	4.43	:	0.159
2.	Corn; soy beans	1	:	4.45	:	0.170
5.	Corn; tankage	1	:	4.88	:	0.197
3.	Corn; linseed meal	1	:	4.91	:	0.169
1.	Corn	1	:	5.12	:	0.178

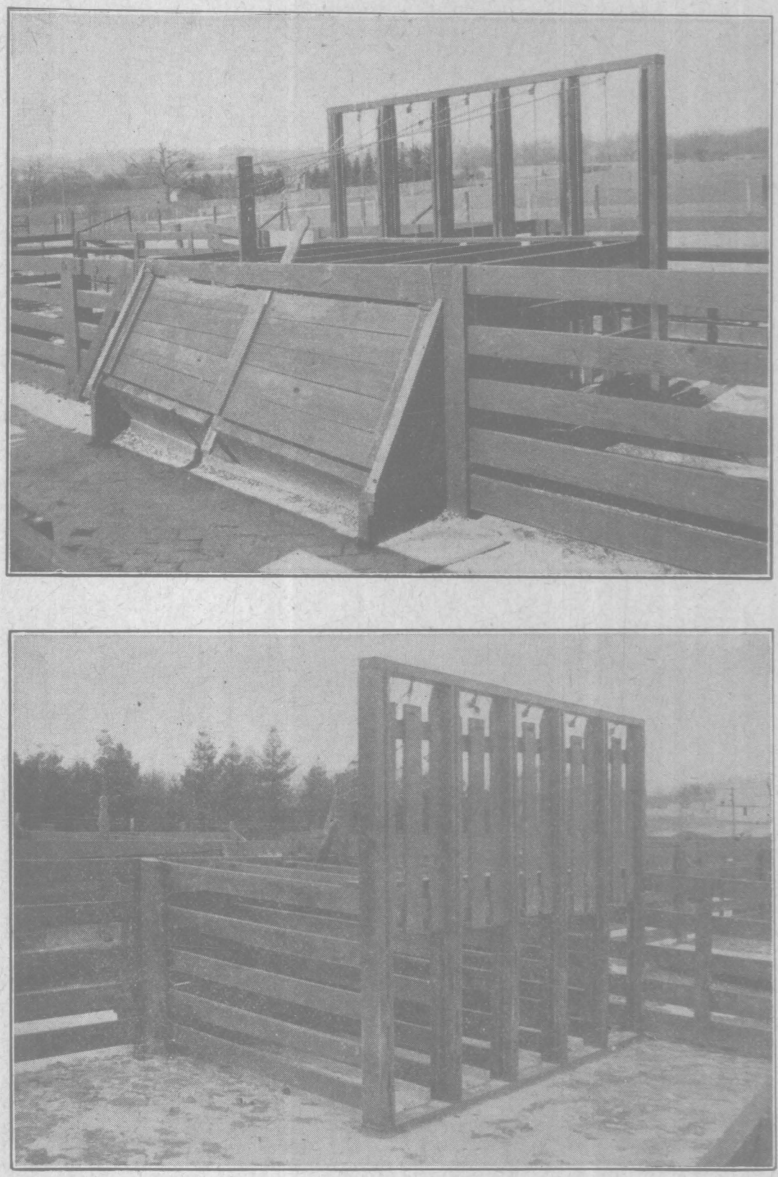
Complete histological blood analyses were made for each pig. Certain individual differences were related to the state of nutrition of the animals within an experimental lot. Other observations were considered to be specific or characteristic for the lot and ration.

Catalase estimations were made on the more important organs and tissues, and certain differences noted between results from the different experimental lots.

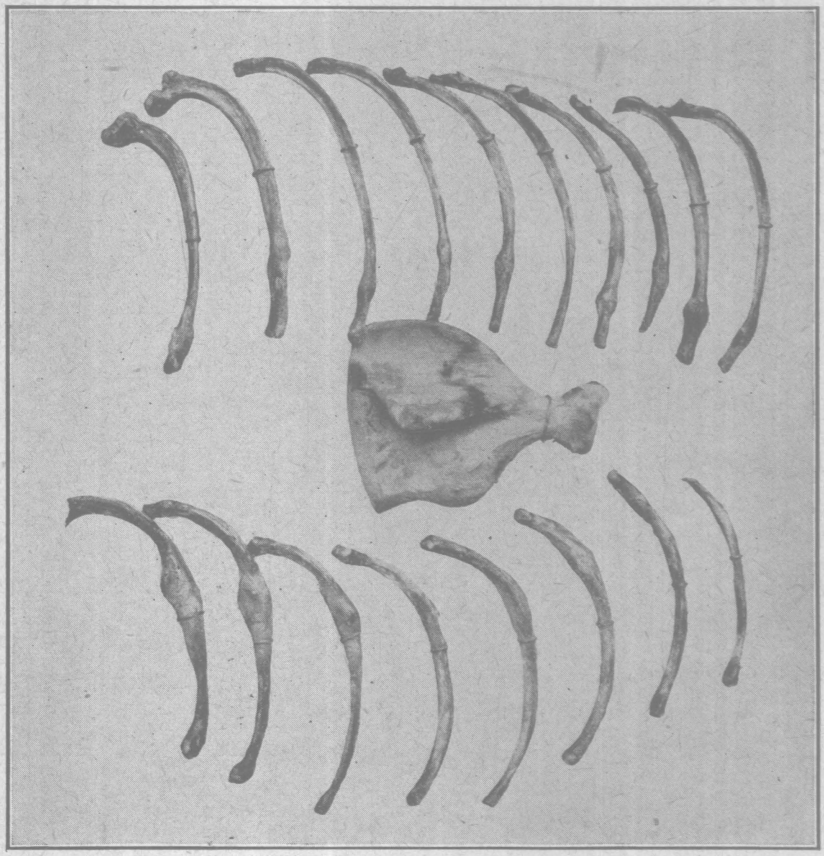
One of the larger bearings of this study, together with the metabolism investigation reported as Ohio Bul. 271, is upon the use of lime in agriculture. The results of these studies reflect the great poverty of cereals in lime, as an element of the food of animals, it being clearly proven that normal growth of the skeleton can not be sustained by the grains. This fact calls especial attention to the leguminous roughages, which, because of their high protein and unparalleled lime content, are the ideal natural supplementary foods for use with the grains. Through the dependence of the legumes, in their growth, upon soil conditions maintained by the presence of lime, and through the heavy draft of the legumes upon the lime content of the soil, this matter of the normal growth of animals is naturally related to this fundamental agricultural consideration.

Paved lots for experimental feeding of swine

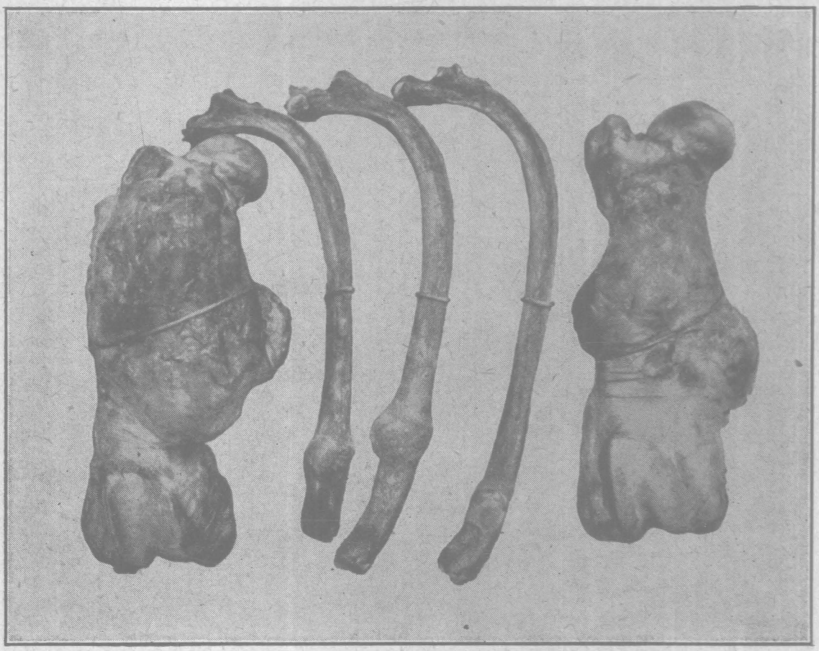
Movable houses and fences for handling breeding swine



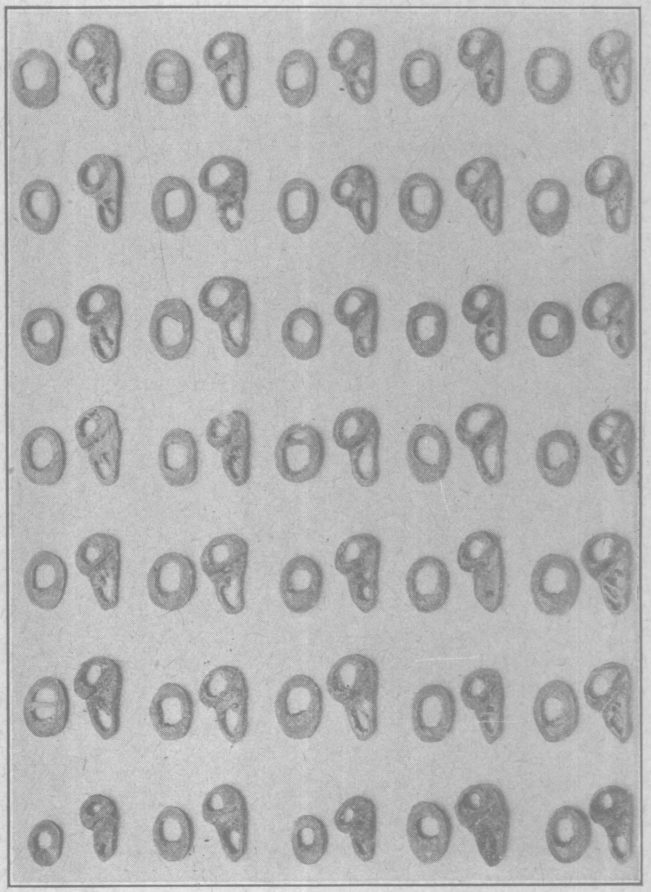
Pens used in individual feeding—Front and rear views



Abnormal bones—See page 126

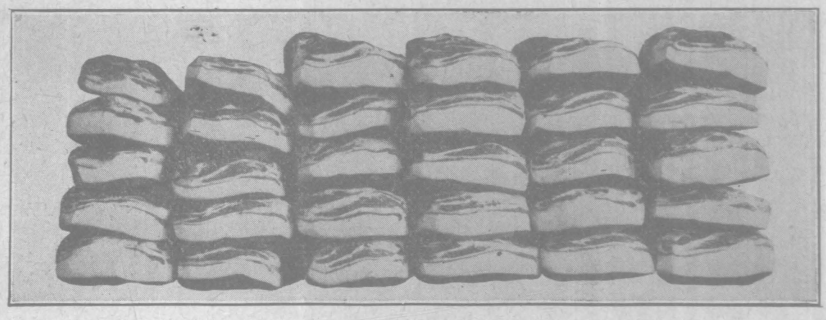


Abnormal bones—See page 126



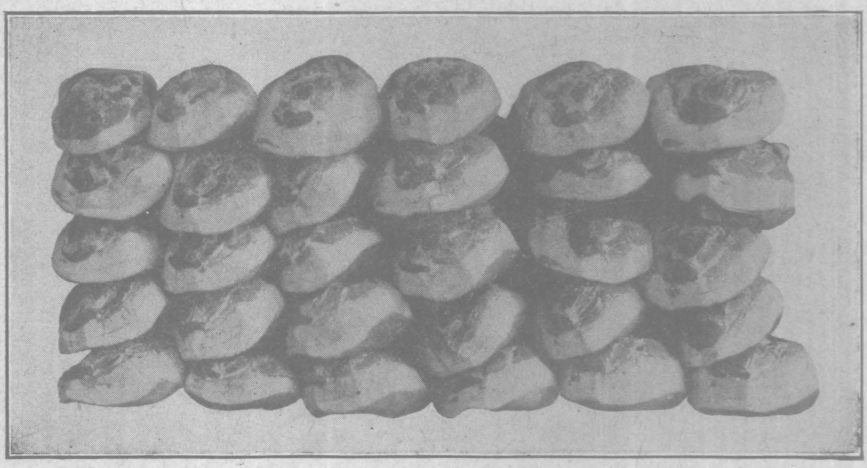
Cross Section of Humerus, Ulna and Radius

Shoulders—Fresh



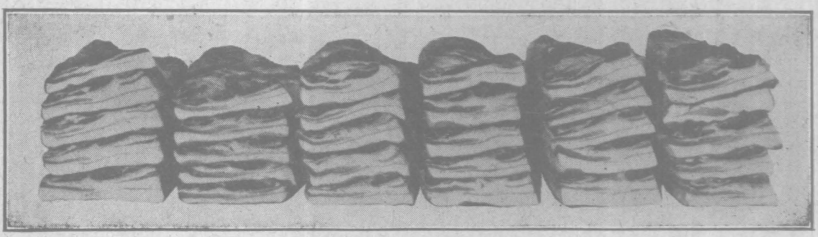
Corn | Corn; soy-beans | Corn; linseed meal | Corn; middlings | Corn; tankage | Corn; skim milk

Hams—Fresh



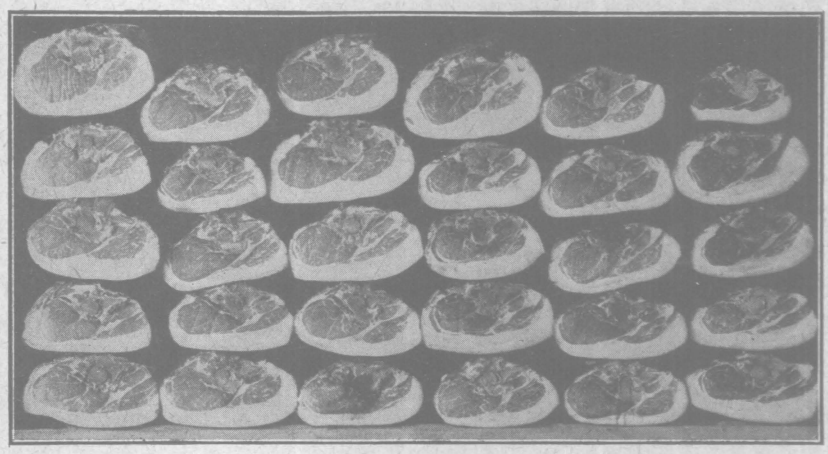
Corn | Corn; soy-beans | Corn; linseed meal | Corn; middlings | Corn; tankage | Corn; skim milk

Bacon—Fresh



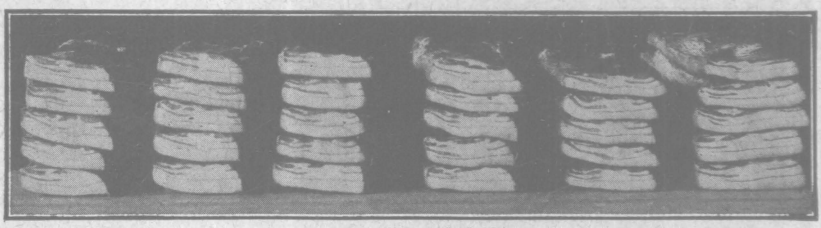
Corn | Corn; soy-beans | Corn; linseed meal | Corn; middlings | Corn; tankage | Corn; skim milk

Hams—Cured



Corn; milk | Corn; tankage | Corn; middlings | Corn; linseed meal | Corn; soy-beans | Corn

Bacon—Cured



Corn; milk | Corn tankage | Corn; middlings | Corn; linseed meal | Corn; soy-beans | Corn